Final Report

Operations Assessment Tools

30 September, 2001

1. Introduction

This study was done to inventory applicable operational assessment tools and the metrics associated with those tools. Operations are all of those activities involved in preparing a reusable space vehicle for launch from its arrival at the spaceport until it leaves the ground at launch. Assessment tools are simulations, models and other tools used to assess the level of support required to fully process a reusable space vehicle.

Currently the only reusable space vehicle is the Space Shuttle with it's requisite processing requirements. Space Shuttle processing is the only baseline available to measure operations requirements and costs. Several of the models use the Shuttle as their baseline. Shuttle operations also provide baseline data for critical metrics.

The Reusable Space Transportation System (RSTS) application requirements document includes an Operation Assessment Tool Requirement in section 6.1.

2. Methodology

2.1. Review the studies and models being prepared for RSTS assessment and other industry studies.
2.2. Extract a list of metrics from these studies and models.
2.3 Create Operational Tool Metric Matrix
2.4 Relate RSTS requirements to Metric Matrix and Operational Tools

3. Operations Assessment Tools Review

AATe – Architectural Assessment Tool enhanced

The AATe model focuses on costs associated with vehicle processing. Costs are broken down into areas such as depot costs, turnaround costs, integration costs, etc. Critical metrics include flight rate, number of vehicles, and pounds per year flown.

COMET / OCM - Conceptual Operations Manpower Estimating Tool / Operations Cost Model

The two models together form the overall OCM structure. COMET estimates the manpower required to perform the Flight Planning and Vehicle Processing activities for flight and launch operations. OCM uses the manpower estimates from COMET to estimate the launch and flight operations costs.

LSOCM / SOCM - Modified Launch Systems Operations Cost Model / Space Operations Cost Model

Currently, SOCM Version 1.0 is available and it models planetary and earth orbiting robotic science missions. The model estimates post-launch mission operations and data analysis staffing and cost requirements and includes cost relationships.

A prototype of LSOCM was evaluated as part of this study. It is a tool to predict the operations and support costs of new and modified reusable launch systems. The current tool uses existing tools including: COMET, OCM and RMAT. The model is being improved and the development team is in the process of validating the algorithms to yield valid cost estimations.

OIA - Operations Impact Assessor

The OIA tool defines a component as an object. An object is an assembly of parts that have processing tasks and resource and facility requirements. The OIA tool can model a conceptual component and its processing tasks to help evaluate both operability and processing requirements such as support equipment, facility utilization, labor, and processing schedules.

OSAMS - Operations Simulation and Analysis Modeling System

This tool is incomplete and was not available.
OSAMS is a modeling system for analysis of the complete lifecycle of a reusable vehicle. The system is intended to provide processing requirement information as well as cost data.

RMAT - Reliability Maintainability Analysis Tool

This tool is based on a comparison between aircraft and Shuttle reliability and maintenance (R&M) characteristics for similar systems. A reference comparison of R&M parameters between the aircraft and Shuttle included support parameters such as maintenance burden, processing times, staffing and fleet size, subsystem weights, vehicle dimensions and other system specific variables. The model can give estimates of a vehicle R&M level based on their comparability.

RRCS – Reusable Launch Vehicle (RLV) Repair Cycle Simulator

A simulation tool designed specifically for the evaluation of alternative resource strategies for the RLV program. The model considers two classes of RLV parts that undergo regular maintenance and included the basic components for modeling maintenance cycle pattern and the ground maintenance schedule

ShuttleSim - Shuttle Processing Flow Simulation

This tool is a macro level simulation model for the Shuttle operations. This model may be used to determine the effect of various parameters on expected flight rate for example, Orbiter Processing Facility (OPF), Vehicle Assembly Building (VAB), Mobile Launcher Platforms (MLP), and launch pad processing times and the number of orbiters, OPFs, VABs, Launch Pads, and the utilization of each facility.

Vision SpacePort

The Spaceport Synergy Team is developing a cost and performance modeling tool for integrated vehicle and spaceport concepts. This model will use information and requirements of launch systems to estimate the cost and throughput performance of future spaceport architectures. The tool will show the designer how different vehicles impact launch site infrastructure, cost, and cycle times.

A planned visualization portion of the model is a 3-D visual representation of the facilities. A three dimensional launch site infrastructure models positioned on a two-dimensional ground reference will allow the user to fly through the model and examine the infrastructure from different perspectives. Many areas of the 3D model are hyperlinked to data sheets for cost and cycle time information in support of a particular function

4. Matrices

4.1. Critical RLV Metrics/Operations Tool Assessment Matrix

This matrix was developed to identify the key metrics needed to assess operational tools for RLV studies. The metrics were determined from interviewing personnel, analyzing modeling tools, literature, and from experiential sources. This set of metrics provided a wide range of applicability. This research also lead to the modeling tools identified in the matrix.

Each metric was classified into one of, currently, four classifications: Concept Design, Mission, Ground Support, System, or Cost. The metrics were then sorted and grouped. If a new category is needed it can be easily added. The percentage of metrics refers to the number of metrics used by a tool in each of the classifications.

Additionally, the matrix correlates the Reusable Space Transportation System (RSTS) Requirements to the metrics identified in this study. Each metric is examined against each RSTS requirement. The second matrix in section 4.2 correlates the RSTS requirements to the various Operations and Maintenance Tools. This provides a cross reference and correlation view.

Category and Metric	Category	RSTS Requirements											AATe	Vision Space Port	OIA	Shuttle Sim	LSOCMSOCM	RMAT	OCM	COMET	RRCS
		6.1.1	6.1.2	6.1.3	6.1.4	6.1.5	6.1.6	6.1.7	6.1.8	6.1.9	6.1.10	6.1.11									
Itegrat-able with PHOENIX													**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
Integrated with PHOENIX Currently													**Y**			**Y**					
% of Metrics													**45%**	**35%**	**50%**	**39%**	**61%**	**24%**	**13%**	**22%**	**26%**
RSTS Requirements Fit																					
Concept Design	**1**												**66%**	**48%**	**45%**	**55%**	**83%**	**31%**	**10%**	**45%**	**17%**
Turn Around Time	1	x	x	x							x	x	O	I	I	O	O	O			I
Mass to Orbit/Year	1	x	x	x							x	x	I		I						
Mean Time To Repair	1	x	x	x	x	x	x				x	x				I		I			I
Mean Time Between Failure	1	x	x	x	x	x	x				x	x			I/O	I					I
MDT (Mean Down Time)	1	x	x	x	x	x	x				x	x			I/O	I					I
Reusable/Expendable Launch Vehs	1	x	x	x							x	x	O	I		I	I/O	O	I/O	I/O	I
Crew Size	1	x		x							x	x					I	I		I	
Safing operations		x		x			x			x	x	x		I	I						
Payload Capacity	1	x	x	x							x	x	O	I	I						
SSTO/TSTO/Expendable Stages	1	x	x	x				x			x	x	I	I	I	I	I			I	
Number of Stages	1	x	x	x							x	x	I	I		I	I			I	
Stacking Operations Required?	1	x	x	x				x			x	x	I			I	I			I	
Number of Expendable Stages or Expendable Tanks	1	x		x				x			x	x		I			I			I	
Tanks/Tanking Operations	1	x	x	x				x			x	x	I		I	I	I/O				
Total Volume/Mass	1	x	x	x							x	x	I				I	I			
Vehicle Fill Time	1	x		x			x		x		x	x			I						
Crew Size (Metrics/Skills/Hours)	1	x		x						x	x	x					I/O	O	I/O	I	
Estimated Life Span of Vehicle	1	x		x							x	x		I	I		I				
Engine Type	1	x	x	x							x	x	I				I	I		I	
Fuel/Oxidizer Type	1	x	x	x							x	x	I	I			I	I		I	
Power System of Vehicle	1	x	x	x							x	x	I				I				
GNC Methodology	1	x		x							x	x					I				
Vehicle Comm	1	x		x							x	x					I				
Thermal Protection Type	1	x	x	x							x	x	I	I			I			I	
Element Delivery Type to Spaceport	1	x		x							x	x				I	I				
Element Assembly/Integration	1	x	x	x				x			x	x	I		I	I	I/O			I	
Number of Integrations Required	1	x	x	x				x			x	x	I		I	I	I			I	
Stage to stage Integration	1	x	x	x				x			x	x	I	I		I	I	I			

Category and Metric	Category	6.1.1	6.1.2	6.1.3	6.1.4	6.1.5	6.1.6	6.1.7	6.1.8	6.1.9	6.1.10	6.1.11	AATe	Vision Space Port	OIA	Shuttle Sim	LSOCMSOCM	RMAT	OCM	COMET	RRCS
Fuel Toxicity/Hazard/Explosive	1	x	x	x							x	x	I		I		I				
		RSTS Requirements																			
Mission	**2**												**43%**	**43%**	**61%**	**57%**	**74%**	**17%**	**17%**	**39%**	**13%**
Flight Rate	2	x	x	x							x	x	O	I		O	I/O		I	I	
Fleet Size	2	x	x	x							x	x	I	I		I	O				
Safing Operations	2	x	x	x				x			x	x		I		O					
Landing Method	2	x	x	x				x			x	x	I	I		I	I/O			I	
Landing Turn Around Time	2	x	x	x			x				x	x	I	I	I	I	I				I
Payloads/Containers	2	x	x	x				x			x	x				I	I			I	
Number of Payloads/Vehicle	2	x		x				x			x	x		I			I			I	
Pre Load Processing Time	2	x		x			x			x	x	x			I		I				
Post Load Processing	2	x		x			x			x	x	x			I		I				
Stage recovery Time	2	x	x	x			x				x	x	I	I	I	I	I				
Payload prep time	2	x		x			x			x	x	x			I						
Payload integration time	2	x	x	x			x			x	x	x	I		I	I	I				
Transport time	2	x	x	x			x				x	x	I		I	I	I				
Percentage Time on Schedule	2	x		x			x				x	x									I
Vehicle refurn time	2	x	x	x	x		x			x	x	x	I		I/O	I					I
Flights per Year	2	x	x	x							x	x	O	I	I	O	I/O			I	
Mating Time for components	2	x	x	x			x			x	x	x			I	I		I			
Flight Control Personnel Headcount	2	x		x						x	x	x			I		O		I	O	
Range Personnel Headcount	2	x		x					x	x	x	x			I		O	I	I	O	
Target Orbit	2	x		x							x	x									
Pressurization System	2	x		x				x			x	x	I				I				
Average Vehicle Flight Duration	2	x	x	x						x	x	x		I	I	I	I	I		I	
Flight Operations Management	2	x	x	x					x	x	x	x		I	I		I/O	I	I	I/O	
Ground Support	**3**												**23%**	**10%**	**67%**	**43%**	**53%**	**30%**	**3%**	**3%**	**47%**
Vehicle inspection time	3	x	x	x			x			x	x	x			I	I	O				I
Engine inspection time	3	x	x	x			x			x	x	x			I	I	O				I
Final Assembly Location	3	x	x	x				x			x	x				I					
MH (Man Hours)	3	x		x			x		x		x	x			I		O				I
Ground Support Equipment	3	x	x	x				x			x	x		I		I	I/O				
Launch Control/Landing Control and Flight Support MDT	3	x		x		x	x				x	x			I			I			
Ground Support Crews Number Required	3	x	x	x				x	x	x	x	x		I	I	I		I			I

Ground Support Crews MH	3	x		x				x	x	x	x	x			I			I			
Category and Metric	Category	RSTS Requirements											AATe	Vision Space Port	OIA	Shuttle Sim	LSOCMSOCM	RMAT	OCM	COMET	RRCS
		6.1.1	6.1.2	6.1.3	6.1.4	6.1.5	6.1.6	6.1.7	6.1.8	6.1.9	6.1.10	6.1.11									
Flight Crew Support	3	x		x					x	x	x	x					I/O		I	I/O	
Mission Specialist Crew Support	3	x		x					x	x	x	x									
Ground Support LRU and SRU Tracking	3	x		x			x	x			x	x			I						I
Ground Support Turn Around Time	3	x	x	x	x	x	x			x	x	x	I		I		I/O				I
Ground Support Mean Time To Repair	3	x		x	x	x	x				x	x			I	I					I
Ground Support Mean Time Between Failure	3	x		x	x		x				x	x			I	I					I
Facilities Required SqFt	3	x		x				x			x	x					O				
Number of non-repairable failures	3	x		x							x	x			I						I
Complex Servicing Operations NumberRequired	3	x		x		x	x	x		x	x	x			I						I
Complex Servicing Operations Turn Around Time	3	x	x	x			x			x	x	x			I	I		I			I
Number of Gases	3	x	x	x				x			x	x	I		I		I				
Amount of Storage Required Gases	3	x	x	x				x			x	x	I				I				
Number of Fluids per vehicle	3	x	x	x				x			x	x	I		I		I				
Volume of Storage Required	3	x	x	x				x			x	x	I				I				
Number of Toxics per vehicle	3	x		x				x			x	x			I		I				
Spares and Spare Parts SqFt storage space	3	x		x				x			x	x					O	I/O			
Number of Critical Parts/Operations	3	x	x	x			x	x			x	x	I								I
Engine refurb time	3	x	x	x			x				x	x		I	I	I	O	I			I
Surface Transport Method	3	x	x	x			x				x	x				I					
Element Assembly Time	3	x	x	x			x				x	x			I/O	I	I/O	I			I
Propellant Servicing & Loading-Time to deliver	3	x	x	x			x				x	x	I		I	I	I/O	I			
Post Flight Ferry Mode	3	x	x	x			x				x	x			I	I		I			
System	**4**												**29%**	**43%**	**43%**	**0%**	**0%**	**29%**	**0%**	**0%**	**57%**
Reliability	4	x	x	x	x						x	x	I	I				I/O			
Time to fix QC	4	x		x	x		x				x	x			1						I
Ec impact	4	x		x							x	x									
Time between failure	4	x		x	x	x	x				x	x			1			I			I

QC Criteria	4	x	x	x	x						x	x	I								I
Percentage pass QC	4	x		x	x						x	x		I							
		RSTS Requirements																			
Category and Metric	Category	6.1.1	6.1.2	6.1.3	6.1.4	6.1.5	6.1.6	6.1.7	6.1.8	6.1.9	6.1.10	6.1.11	AATe	Vision Space Port	OIA	Shuttle Sim	LSOCMSOCM	RMAT	OCM	COMET	RRCS
Safety compliance time	4	x		x	x		x				x	x		I	1						I
Cost	**5**												**67%**	**50%**	**0%**	**0%**	**50%**	**50%**	**50%**	**0%**	**0%**
Direct Vehicle Cost	5	x	x	x							x	x	I	I							
Fixed Annual Labor Cost	5	x		x							x	x		I			O	I/O	O		
Fixed Annual Materials and ODC	5	x		x							x	x		I			O	I/O	O		
Insurance Cost	5	x	x	x							x	x	I					I			
Variable Annual Materials and ODC	5	x	x	x							x	x	O	I			O	I/O			
GSE Outfitting Cost	5	x	x	x							x	x	O				O	I/O			
Taxes/Cost of Money	5	x	x	x							x	x	I						I/O		
Profit Margin	5	x		x							x	x							I/O		
Internal Rate of Return	5	x	x	x							x	x	I	I							
Safety compliance cost	5	x		x							x	x							I/O		
Variable Annual Labor Cost	5	x	x	x							x	x	O	I			O		O		
Facility Acquisition Costs	5	x		x							x	x	O				I/O	I			
LEGEND: I - O - Output; I - Input																					

4.2 Reusable Space Transportation System (RSTS) Requirement/Ops Tool Correlation Matrix

This second matrix correlates the RSTS Requirements to the various Operations and Maintenance Tools identified and studied. This cross reference enables the ability to correlate the metric and tool to the RSTS requirement.

RSTS Requirement	Operation & Maintenance Tools								
	AATe	Vision Space Port	OIA	Shuttle Sim	LSOCMSOCM	RMAT	OCM	COMET	RRCS
6.1.1	x	x	x	x	x	x	x	x	x
6.1.2	x	x	x	x	x	x	x	x	x
6.1.3	x	x	x	x	x	x	x	x	x
6.1.4	x	x		x		x			x
6.1.5		x	x	x		x			x
6.1.6	x	x	x	x	x	x			x
6.1.7	x	x	x	x	x			x	x
6.1.8		x	x	x	x	x	x	x	x
6.1.9	x	x	x	x	x	x	x	x	x
6.1.10	x	x	x	x	x	x	x	x	x
6.1.11	x	x	x	x	x	x	x	x	x

5. Conclusions

5.1 General

Each tool evaluated seemed to perform their specific function. There are overlapping capabilities evident in each of the tools. This was shown in the Critical RLV Metrics/Operations Tool Assessment Matrix. No particular tool evaluated was able to completely cover all of the identified metrics. If several of the tools could be used together it could be enough to complete the model. An integration tool, such as Phoenix Model Center, could be used to combine the individual tools by aligning the process flow and the inputs and outputs between them.

Assuming the individual tools can be integrated into a single environment, all of the Reusable Space Transportation System (RSTS) requirements outlined in section 6.1 of the RSTS Requirements Document could be satisfied.

5.2 **Issues**

1. The critical flight elements for RSTS have yet to be designed and constructed. Any operations tools must be designed to work at the conceptual design stage.
2. There seems to be a lack of organized data about current processes. Discussions with tool developers revealed a shortage of organized historical data about the details of shuttle processing. This data must be gathered so that it may be used to validate models for future vehicles.
3. To normalize the metrics among and within the tools, the division between the cost models, operations assessment models, and other tools must be defined.
4. There is a need to determine which operations should be modeled and to try to establish a priority to the information that can be extracted from the model.

5.3 Future

Evaluate the models and tools from a system level architectural view to determine the operations and maintenance tasks required for future RLVs. This architecture could be used as a guide to integrating everything into one logical tool. An implementation plan for integrating each subsystem should be done. The plan should be implemented and validated.

6. REFERENCES

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